EVOLVING UHF SATCOM DAMA STANDARDS:
IMPACT ON GBS REACH-BACK CAPABILITIES

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ABSTRACT

The Navy has plans to transition from its current system of many special purpose data exchange protocols to a single system that uses standard open system network protocols. The new system is expected to use UHF SATCOM to provide low speed data links for the request of data and GBS for high-speed data delivery. This paper looks at changes that need to be made to the UHF SATCOM demand assigned multiple access (DAMA) standards to efficiently handle future user communication requirements. The impact on GBS reach-back applications is emphasized.

INTRODUCTION

The introduction of the Global Broadcast Service (GBS) has opened the door for many new opportunities in the world of military communications. GBS will provide a high-speed delivery service for tactical data to locations almost anywhere in the world. The addition of a reach-back channel, making the GBS network bi-directional, would make it possible for users to request and acknowledge data delivery from the GBS. The Automated Digital Network System (ADNS), a component of the Joint Maritime Communications Strategy (JMCOMS), is trying to create a robust and flexible networking environment by incorporating Internet Protocols (IP) into future Naval communication systems. This paper explores the possibility of using UHF satellite communication (SATCOM) resources and IP for this reach-back function.

We start with a brief description of UHF SATCOM with emphasis on the scarcity of UHF resources. The demand for UHF communication resources has always exceeded the supply. DAMA was developed as an attempt to cope with the scarcity of UHF SATCOM resources. DAMA combines Time Division Multiple Access (TDMA) with demand assignment of

communication resources to greatly increase the number of users that each channel can support. However, the introduction of DAMA has spawned a ten-fold increase in the number of UHF capable terminals, so the problem is about to get much worse.

The paper then describes the characteristics of a bi-directional GBS system and the subsequent requirement for a reach-back channel. For many applications the up link and down link communication requirements are asymmetric, allowing the reach-back channel to operate at a much lower data rate than the GBS down link channel. UHF SATCOM is a natural choice for this reach-back function; however, the existing DAMA protocols do not efficiently handle IP datagrams.

The Joint Interoperability and Engineering Organization (JIEO) is currently investigating the need to update the DAMA standards to better meet current user requirements. Revisions are being considered which would provide a tailored protocol that will be ideal for use as a GBS reach-back channel. Examples of new DAMA protocols that would suit this purpose are given. The paper concludes by discussing reasons why developing protocols for the efficient handling of IP datagrams over UHF DAMA may no longer be cost effective. Alternative satellite architectures are considered that have the possibility for improving future satellite communications.

BACKGROUND

The military UHF SATCOM frequency allocation is divided into a set of independent 5-kHz and 25-kHz bandwidth channels. Satellite transponders for each channel are nonregenerative and hard limiting. UHF satellite channels can be accessed by small, inexpensive terminals using non-directional antennas, and can operate in bad weather and through foliage that would block other satellite frequency bands. These characteristics of UHF make it the logical choice for GBS reach-back applications for mobile terminals.

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Unfortunately, UHF channels are in short supply and demand for them greatly exceeds the available resources.

A pair of UHF Follow-On (UFO) satellites operates in each of four overlapping satellite coverage areas providing around-the-world coverage. A satellite pair operating together provides a total of 78 channels for use within each operating area. Of these 78 channels, there are 42 5-kHz channels, 34 25-kHz channels, and two 25-kHz fleet broadcast down links which are fed by jam resistant SHF and EHF up links. Channel capacity is limited by our nation's UHF spectrum allocation, not by our ability to build and launch satellites.

In addition to the scarcity of resources, throughput is very limited on UHF SATCOM channels. The nonregenerative satellite transponders do allow terminals to use modern modulation and coding techniques, but the hard limiting prevents use of some bandwidth efficient modulation techniques that depend on amplitude modulation. Using Multi-h Continuous Phase Modulation it is possible to operate at rates as high as 9600 bps over a 5-kHz channel and 48 kbps over a 25-kHz channel, but reliable operation at these rates requires better link margins than many small terminals can achieve [3].

EVOLUTION OF DAMA

Demand assigned multiple access (DAMA) standards were introduced in an attempt to make more efficient use of the limited UHF SATCOM resources. DAMA provides multiple access to a single channel through use of TDMA. Using TDMA, channel time is divided into repetitive equal-length intervals known as frames, and frames are subdivided into smaller intervals know as time slots. There are three general types of time slots: (1) orderwire time slots, used for access control and timing, (2) system support time slots, used for terminal ranging, and (3) communication time slots, used for baseband communications. A communication time slot can support a half-duplex communication service. Time slots for networks that operate 24 hours a day are assigned automatically by the channel control system. Any user terminal can request temporary use of a time slot by transmitting a request in a return orderwire time slot. The channel control system assigns time slots based on availability of resources and the priority of the requested communication service. Point-to-point, conference, and network communication services are supported.

The two current DAMA standards that define operation over UHF satellite channels are MIL-STD-188-182A for operation on 5-kHz channels and MIL-STD-188-183A for operation on both 5-kHz and 25-kHz

channels. MIL-STD-188-182 was originally designed by the Air Force to provide around-the-world messaging for MAC aircraft. It can support data rates as high as 2400 bps and provides a messaging capability. MIL-STD-188-183 was designed by the Navy to increase circuit availability and reduce radio requirements by multiplexing several networks on each channel. It can support data rates as high as 16 kbps, but generally is used in a mode where the maximum data rate available is 2400 bps.

The problem of over-demand for UHF circuits became so great that the Joint Chiefs of Staff (JCS) mandated a requirement to transition all UHF SATCOM users over to DAMA. JCS made the decision to require all terminals using UHF SATCOM to be certified to be interoperable with both MIL-STD-188-182A and MIL-STD-188-183A. While each standard may have been sufficient for its intended purpose, the two standards are not interoperable with each other and are not capable of satisfying all current and developing user requirements. Even with the recent publication of the improved "A" versions for both standards, interoperability and control problems still exist.

DAMA protocols have not kept pace with evolving communication requirements. There are many more requirements for voice circuits now than existed when the original DAMA standards were written, and these requirements compete for the limited number of 2400 bps time slots available. Most of the older data protocols in use today were designed to operate synchronously over circuits operating at known fixed rates. Many existing data communication requirements are being satisfied using 75 bps circuits. While the Navy still operates 75 bps "teletype" networks, not many new systems are being developed to operate on circuits that run this slowly. Newer data protocols are generally designed to move data asynchronously. Because of these and other changes in user needs, JIEO is considering updating the standards again. An improved capability for handling data rate-independent protocols is one of their highest priority goals.

CHARACTERISTICS OF A GBS REACH-BACK CHANNEL

The GBS high-speed unidirectional information delivery system could be used more efficiently if a reach-back communication path existed to allow users to acknowledge receipt of information and request new information. This reach-back channel could take on many forms. Information requests and acknowledgments could be performed manually over existing voice or messaging systems. Alternatively, protocols tailored to the GBS system could be developed

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to allow the automatic request and acknowledgments of information using existing messaging systems. However, the use of standard commercial internet protocols would allow the use of email, World Wide Web (WWW) browsing, and other file transfer protocols that users are already familiar with. This paper addresses the possibility of using commercial IP operating over UHF DAMA circuits for the reach-back channel. The GBS system envisioned here is a bi-directional, asymmetric communication link using GBS for the high-speed down link and UHF SATCOM for the low-speed up link. GBS would typically deliver tactical and time sensitive information to users deployed in a theater scenario. The up link, the focus of this paper, would be used mainly to request and acknowledge receipt of information.

Most of the data traffic on a typical IP system is moving downstream to the user. The user is almost always sending out very little information. What does go out is often only a mouse click representing a request for more data. Sending email requires a larger portion of bandwidth for a short duration. The IP reach-back channel can be characterized as one which most of the time uses very little bandwidth but on occasion requires a lot of bandwidth. We would like to have a GBS reach-back channel that can provide this type of service whether IP or some other high level protocol is being used.

IP OVER UHF SATCOM TODAY

UHF SATCOM is being used today to provide IP services of a sufficient quality to perform the GBS reach-back function. Existing DAMA protocols can be used for the request and assignment of a circuit between the user and the Internet Service provider. To get the highest bit rate and lowest delay possible, a user would request a Demand Assigned Single Access (DASA) channel. This form of assignment allows the requesting user exclusive use of the entire 5- or 25-kHz channel bandwidth. The delay time on a DASA channel is about 250 milliseconds. This is the 'in flight' time of the IP datagrams traveling to and from the satellite. Although this method provides the highest quality of service available using UHF DAMA, it is unrealistic for each user to be assigned a DASA channel given the resource limitations.

If a DAMA time slot is used, the user would likely be assigned a 2400 bps time slot over which to send data. This method imposes an additional delay because of the frame format used by DAMA. Using 5-kHz DAMA would impose a total delay of about 10 seconds. A delay of this length would probably prohibit the use of IP. A more tolerable delay of about 2 seconds results from

using a 25-kHz DAMA time slot. Most proposed methods for sending IP traffic over UHF channels use 25-kHz DAMA time slots.

Connecting to an Internet Service provider over a requested UHF channel or time slot is analogous to using a dialup modem to make the connection over a telephone line. The user is allotted a fixed bandwidth that remains open until the user hangs up. This situation is appropriate for short sessions in which a user logs on to send and receive email then logs off. However a great deal of bandwidth is typically wasted during periods when no data is being transferred or data is primarily moving in only one direction. Specialized protocols need to be developed to increase the efficiency of use of the UHF channel.

Ideally a UHF channel could be shared using protocols similar to those used for connection to an Ethernet Local Area Network. Users connected to an Ethernet can send a variable length message any time they detect that that the Ethernet is not in use. When only one user is active, the entire bandwidth of the Ethernet is available to that user. When more than one user needs to send data, the bandwidth is shared. Occasionally users will transmit messages at the same time, resulting in a collision between the messages. Collisions on an Ethernet can be detected and resolved within a few microseconds. Unfortunately, the long round-trip delay to the current UHF satellites makes it impossible to detect message collisions in less than a quarter of a second. For this reason, protocols for sharing a UHF channel may need to be designed to minimize the possibility of contention.

ADNS has developed protocols that allow a group of users to share a single UHF DAMA time slot. Each member of the ADNS network is in turn assigned a set of consecutive time slots for transmission of IP datagrams. This sharing of the channel results in very long delays that would normally cause problems for many of the protocol layers. To minimize these problems, ADNS uses multiple tricks to hide some of the delay from the higher layer protocols. This sharing of the UHF SATCOM resource can work well for internet applications that move relatively large messages where the delay is not directly visible to the user. For applications like browsing the web, where the user expects immediate feedback to each keyboard or mouse action, the delay is probably unacceptable.

The traditional problems with using IP on a satellite link have to do with delay. The Transmission Control Protocol (TCP) was optimized for use on a terrestrial network where both the latency and error rate are very low. Performance suffers greatly when this protocol is used on a satellite system that has both a high delay and

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a comparatively higher error rate. TCP/IP uses a slow start algorithm. When TCP/IP doesn't receive a timely response or receives an error, it assumes congestion has occurred and restarts the algorithm. This requires the retransmission of all packets that have already been transferred but have not been acknowledged. By modifying the IP algorithm such as described in [2], most of the problems caused by satellite delay can be overcome.

REWRITING THE DAMA STANDARD

Most proposals for GBS reach-back systems using UHF involve working within the constraints of MIL-STD-188-183A. This is very limiting because the DAMA waveform was not designed for this type of traffic. The process of revising both the 5-kHz and 25-kHz DAMA standards presents an excellent opportunity to create a unique protocol specifically designed for a GBS reach-back channel. It is unlikely that IP handling will be implemented directly into the waveform. Instead a protocol will be designed to pass data with the characteristics of both general message delivery and the reach-back channel in mind. The protocol will be designed only up to the data link layer with the idea that baseband equipment will provide the higher level protocols. The new protocol will provide the varying levels of bandwidth required by users on the system without wasting valuable bandwidth when it is not needed.

Higher level protocols will be able to work around the problems created by the inherent delay in the system. One way around the delay problem, which has been used with some success, is to use a larger TCP window size [1].

One proposed idea for using UHF SATCOM as a GBS reach-back channel would be to divide a single channel into very small time slots. The channel controller would assign one or more small time slots within each frame to each terminal sharing the frame. The small time slots would provide the entire up link bandwidth required by a terminal when the user is merely reading, pointing the mouse, or typing slowly. When a larger amount of data needs to be sent out, the assigned time slot would be used to send a request for more bandwidth. The channel controller would respond by assigning additional space in future frames until the terminal indicates that all data has been transferred. When more than one terminal simultaneously requires additional bandwidth, the channel controller could divide all unused time between the terminals.

It is possible to control the sharing of a channel through the use of protocols that depend on cooperation between terminals without necessitating the use of a

channel controller. Each terminal would initially capture a nominal time slot using contention-based algorithms. When additional time slots are needed, the terminal would send a message within its nominal time slot stating an intention to use an additional time slot beginning in the next frame. When duplicate requests are made within a frame, the last terminal to make the request would get use of the requested time slot. Terminals would monitor requests made by all other terminals in order to adjust their requests to allow the channel to be shared.

THE FUTURE OF UHF

Caution should be taken before initiating the development of new IP friendly protocols. If the demand on UHF resources is not alleviated then it may not be cost effective to develop the new protocols. The capacity of the UHF SATCOM system may not be able to support the GBS reach-back function.

Computer users on board ships often work in an office environment and want the same high bandwidth IP services normally available in an office. UHF is not capable of providing this high bandwidth service. The Navy is planning to move some of its networks over to SHF and EHF SATCOM, but these satellites are also experiencing high utilization levels. Moving networks over to SHF and EHF SATCOM would provide the Navy with the high quality, high bandwidth service it wants, and at the same time, it would free up badly needed UHF bandwidth for use as a reach-back channel by more disadvantaged users. This would be an ideal time for the Navy to make the transition because most of the Navy is still using legacy UHF equipment that is in need of replacement.

Unfortunately there are technical problems that make using the current SHF and EHF satellite constellations difficult. To communicate over SHF SATCOM requires a large, accurately pointed antenna. This presents two problems. It is hard to find a location on a ship that has an unobstructed view of the satellites and it is very difficult to point an antenna with sufficient accuracy as the ship pitches and rolls. An antenna must be placed high on a ship in order to have a good view of the sky and this placement accentuates the movement of the vessel. EHF requires a smaller antenna but still has the accurate pointing requirement. SHF and EHF are currently used onboard aircraft carriers and other very large ships. Since these types of ships are much larger and more stable than smaller ships, it is easier to install and accurately aim the antenna. The high cost of the equipment needed for SHF and EHF is also more easily justified because of the tactical importance of these ships.

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It is possible that the next generation of UHF satellites will use a Low Earth Orbit (LEO) constellation. LEO satellites orbit at an altitude of around 400 miles, compared to the 22,000-mile orbit of a geostationary satellite. The smaller spot size translates to a 9-dB improvement in link margins, reducing the transmit power required to a level that would allow practical handheld terminals. LEO satellites can be used with non-directional antennas, allowing easier antenna placement on ships, use of non-tracking antennas, and alleviating the requirement for a mobile terminal to point the antenna. At 400 miles, the delay time to the satellite would be just a few milliseconds. This lower delay time would simplify the use of IP over the satellite. Most importantly, the demand for UHF would be eased greatly because frequencies could be reused every several hundred miles. This would improve the outlook for a UHF reach-back system. An obvious disadvantage to this plan is the cost of implementing it. Other technical problems would also have to be addressed. Communication between distant points would require data relay between satellites and global messaging would require distribution of data to a large number of the satellites. Moving SHF to LEO satellites would provide the same benefits for SHF users, and make it easier for ships to move from use of UHF to SHF.

CONCLUSION

UHF SATCOM can be used to provide acceptable service as a reach-back channel using existing DAMA protocols, but IP will not operate efficiently over these channels. New protocols need to be added to the DAMA standards to provide an efficient method for moving data rate-independent messages. The new protocols could be included in the next generation of the DAMA standards that are under development.

Whether or not to go forward with this new protocol design is something that needs to be carefully considered. The direction in which satellite communications moves will affect the practicality of implementing the UHF reach-back protocol. If the over-demand for UHF SATCOM resources does not abate then it may not be cost effective to design the new protocols since there may never be enough UHF capacity to accommodate the reach-back function. However if changes are made which ease demand for UHF resources then the new reach-back protocol should be developed.

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